



REMOTE SENSING, AIR QUALITY, AND PUBLIC HEALTH

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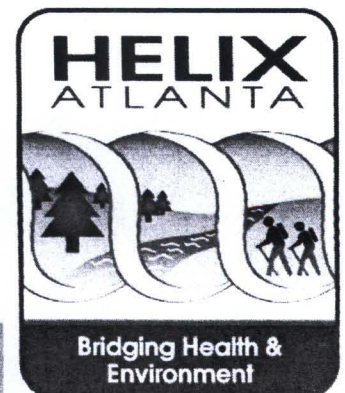
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Hong Kong Urban Workshop, 2008



Public Health Surveillance

- Ongoing systematic collection, analysis, and interpretation of outcome-specific data used to plan, implement, and evaluate public health practice.



Surveillance Information Uses

- Monitor & detect changes in the magnitude & distribution of selected events
- Develop hypotheses for research
- Evaluate interventions
- Facilitate public health decision-making



Types of PH Surveillance

- Prevalence
 - All cases
- Incidence
 - Newly diagnosed cases
- Active
 - Health department initiated
- Passive
 - Health care provider initiated



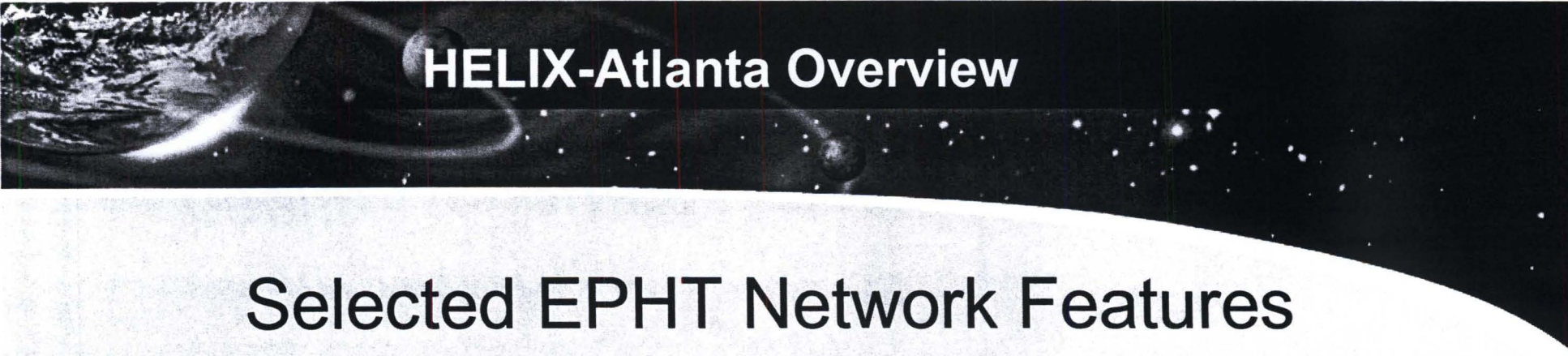


HELIX-Atlanta Overview

CDC's National Environmental Public Health Tracking (EPHT) Program initiated in 2002

- Congressional funding for *development and implementation of a nationwide environmental health tracking network and capacity development in environmental health at State and local health Departments*





HELIX-Atlanta Overview

Selected EPHT Network Features

- Tools for linkage, visualization, analysis, generation of alerts, & reporting
- Internet-based
- Standards-based
- HIPAA compliant
- Access to the network is based on role & purpose

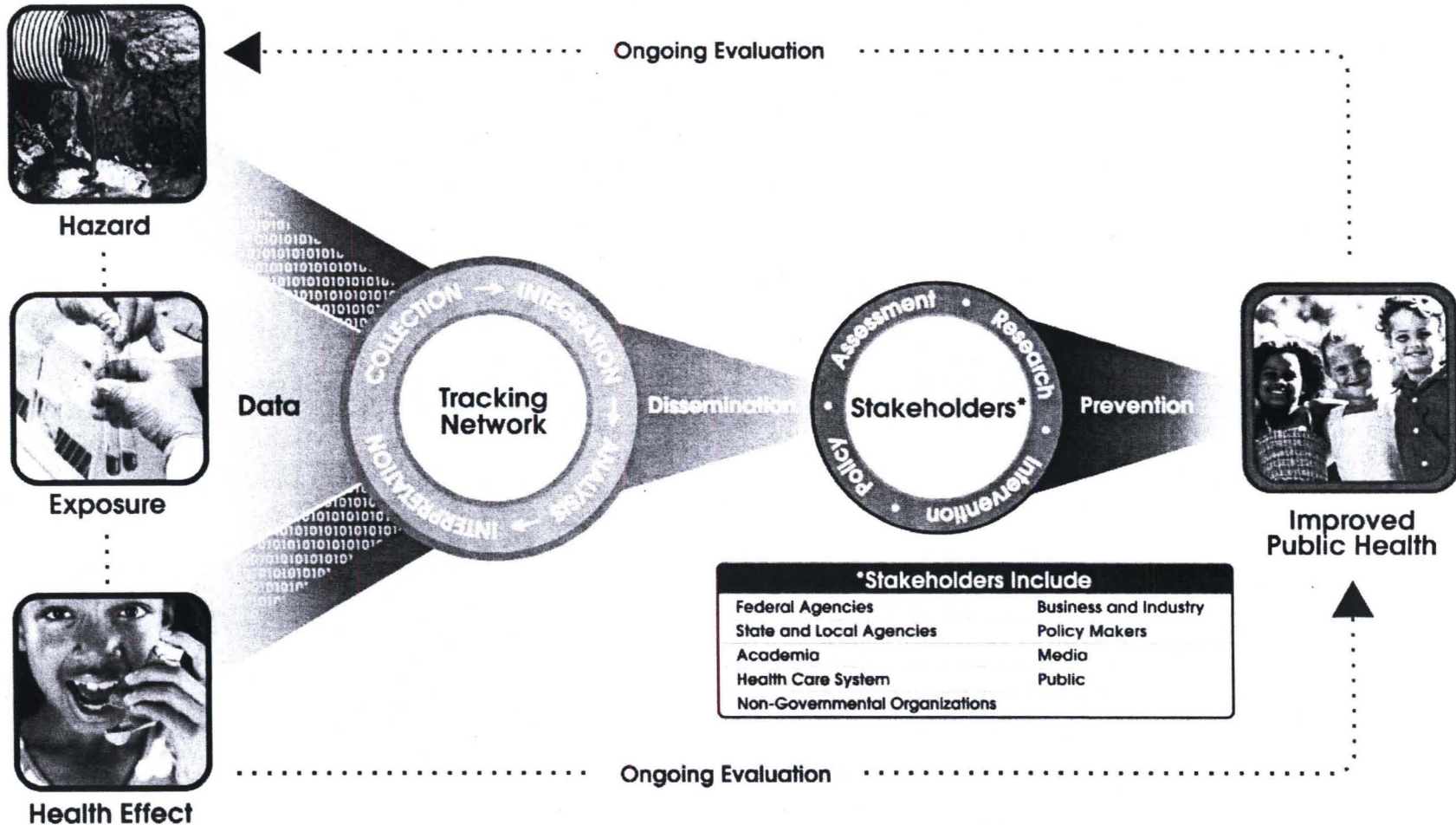


Tracking = Public Health Surveillance

- Environmental public health tracking is the ongoing, systematic collection, integration, analysis, and interpretation of data about the following factors:
 - environmental hazards
 - human exposure to environmental hazards
 - health effects potentially related to exposure to environmental hazards
- Data must be disseminated to plan, implement, and evaluate environmental public health action



ENVIRONMENTAL PUBLIC HEALTH TRACKING



DEPARTMENT OF HEALTH AND HUMAN SERVICES
CENTERS FOR DISEASE CONTROL AND PREVENTION
SAFER • HEALTHIER • PEOPLE





Health Effects, Exposures, Hazards

Health Effects

- Asthma
- Poisoning – heavy metal; CO; pesticides
- Cancer
- Birth Defects
- Other adverse reproductive outcome such as low birth wt, preterm birth
- Developmental disabilities
- Other chronic respiratory disease
- Multiple Sclerosis
- Cardiovascular Disease
- Systemic Lupus Erythematosus
- Amyotrophic lateral sclerosis

Exposures/Hazards

- PCBs
- Heavy metals
- Pesticides
- Environmental tobacco smoke
- Radionuclides
- Asbestos
- Other drinking water contaminants such as trihalomethanes, PCE, TCE,
- Outdoor air contaminants such as particulate matter, ozone, CO and air toxics
- Indoor air contaminants such as mold, carbon monoxide



HELIX-Atlanta

- Provide information regarding the 5-county Metro-Atlanta Area
Clayton, Cobb, DeKalb, Fulton, & Gwinnett
- Integrate environment & public health data into a local network that is part of a national network
- Take action to prevent & control environmentally related health effects





HELIX-Atlanta Overview

- **HELIX-Atlanta was developed to support current and future state and local EPHT programs to implement data linking demonstration projects which could be part of the EPHT Network.**
- **HELIX-Atlanta is a pilot linking project in Atlanta for CDC to learn about the challenges the states will encounter.**
- **NASA/MSFC and the CDC are partners in linking environmental and health data to enhance public health surveillance.**
- **The use of NASA technology creates value – added geospatial products from existing environmental data sources to facilitate public health linkages.**
- **Proving the feasibility of the approach is the main objective**





HELIX-Atlanta Challenges

- **Sharing data between agencies with different missions and mindsets**
- **Protecting confidentiality of information**
- **Ensuring high quality geocoded data**
- **Ensuring appropriate spatial and temporal resolutions of environmental data**
- **Developing sound resources and methods for conducting data linkages and data analysis**





HELIX-Atlanta Respiratory Health Team

RH Team Pilot Data Linkage Project:

Link environmental data related to ground-level PM_{2.5} (NASA+EPA) with health data related to asthma

Goals:

1. Produce and share information on methods useful for integrating and analyzing data on asthma and PM_{2.5} for environmental public health surveillance.
2. Generate information and recommendations valuable to sustaining surveillance of asthma with PM_{2.5} in the Metro-Atlanta area.

Environmental Hazard Measure: Daily PM_{2.5}

Asthma Measure: Daily acute asthma office visits to KP-GA Medical Facilities

Time period: 2001-2003

Linkage Domain: 5-county metropolitan Atlanta



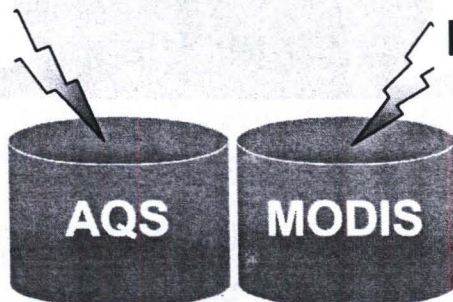
Data Linkage



EPA



NASA



KAISER PERMANENTE

HELIX - Atlanta Team

NCEH

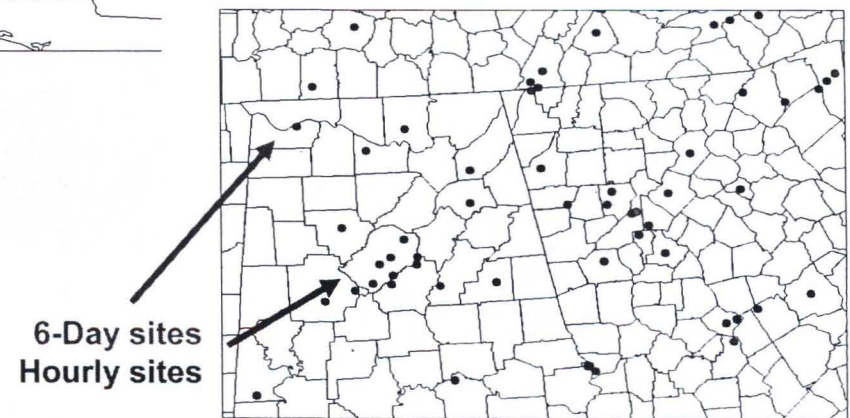
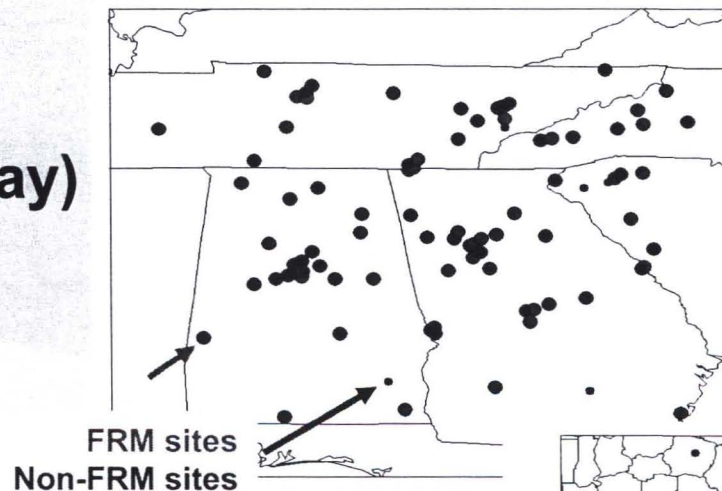
EHTB



Sources of PM_{2.5} data: EPA AQS

EPA Air Quality System (AQS) ground measurements

- National network of air pollution monitors
- Concentrated in urban areas, fewer monitors in rural areas
- Time intervals range from 1 hr to 6 days (daily meas. every 6th day)
- Three monitor types:
 - Federal Reference Method (FRM)
 - Continuous
 - Speciation
- FRM is EPA-accepted standard method; processing time 4-6 weeks



Legend

- Frequency=1hr
- Frequency=1 day
- Frequency=3 days
- Frequency=6 days

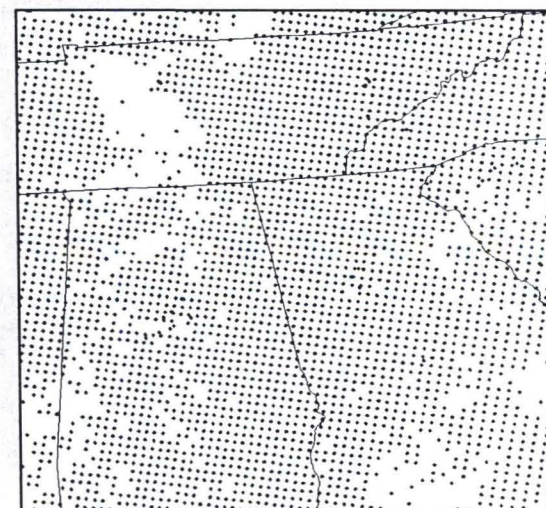
EPA AQS PM_{2.5} Reporting Monitors
on Jan 10, 2004



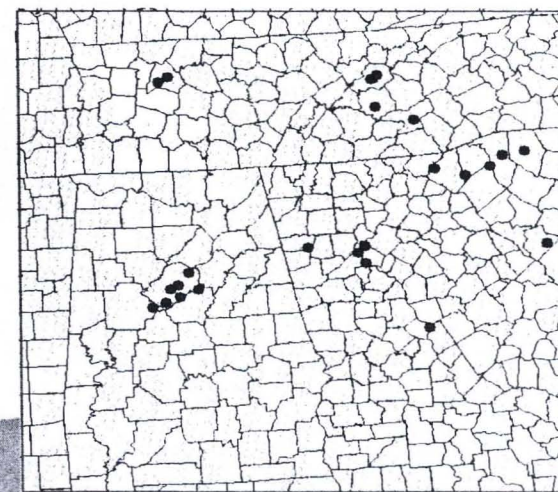
Sources of PM_{2.5} data: MODIS

MODIS Aerosol Optical Depth (AOD)

- AOD is a measure of the total particulate in the atmosphere
- If atmosphere is well mixed, AOD is a good indicator of surface PM_{2.5}
- Enhanced Spatial Coverage
- Provided on a 10x10 km grid
- Available twice per day
(Terra ~10:30 AM, Aqua ~1:30 PM)
- Clear-sky coverage only
- Available since spring 2000



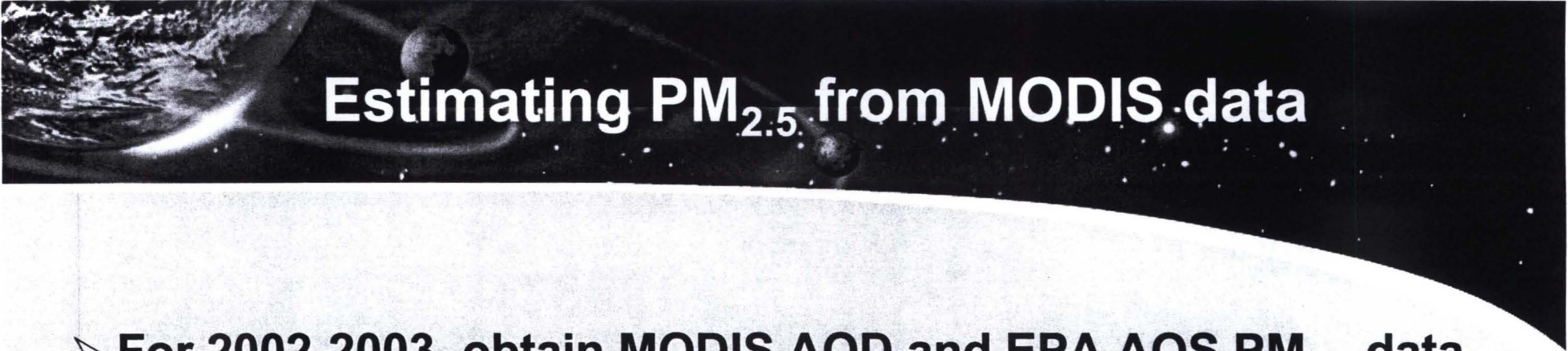
MODIS



AQS



June 25, 2003

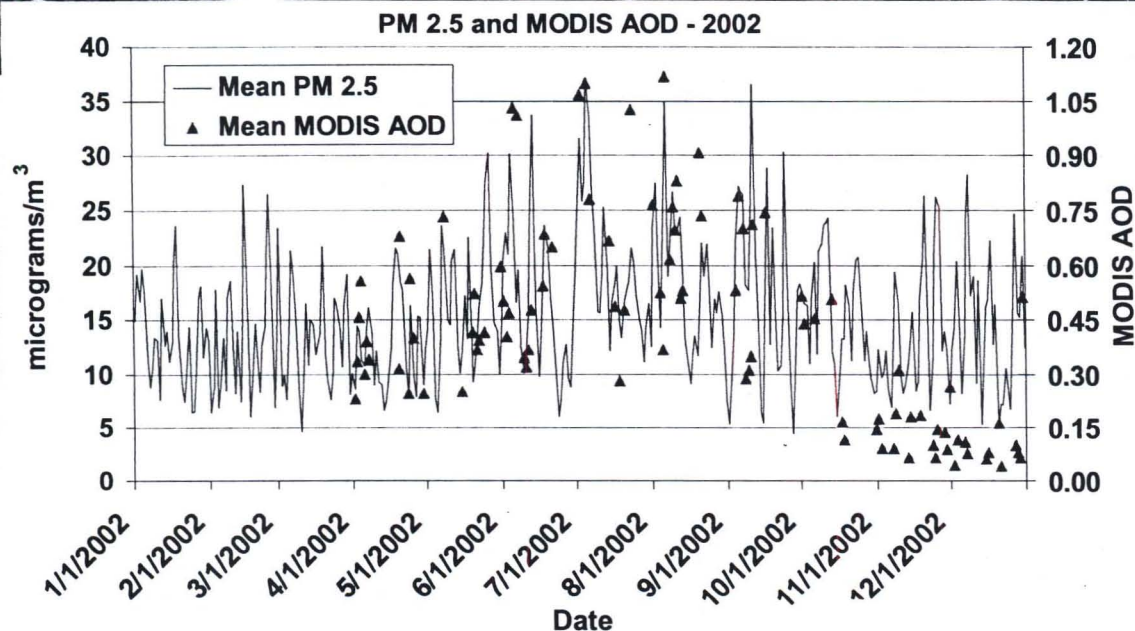


Estimating PM_{2.5} from MODIS data

- For 2002-2003, obtain MODIS AOD and EPA AQS PM_{2.5} data
- Extract AOD data for 5 AQS site locations
- Calculate daily averages from hourly AQS PM_{2.5} data
- Using daily PM_{2.5} averages from all 5 Atlanta AQS sites, determine statistical regression equations between PM_{2.5} and MODIS AOD
- Apply regression equations to estimate PM_{2.5} for each 10 km grid cell across region

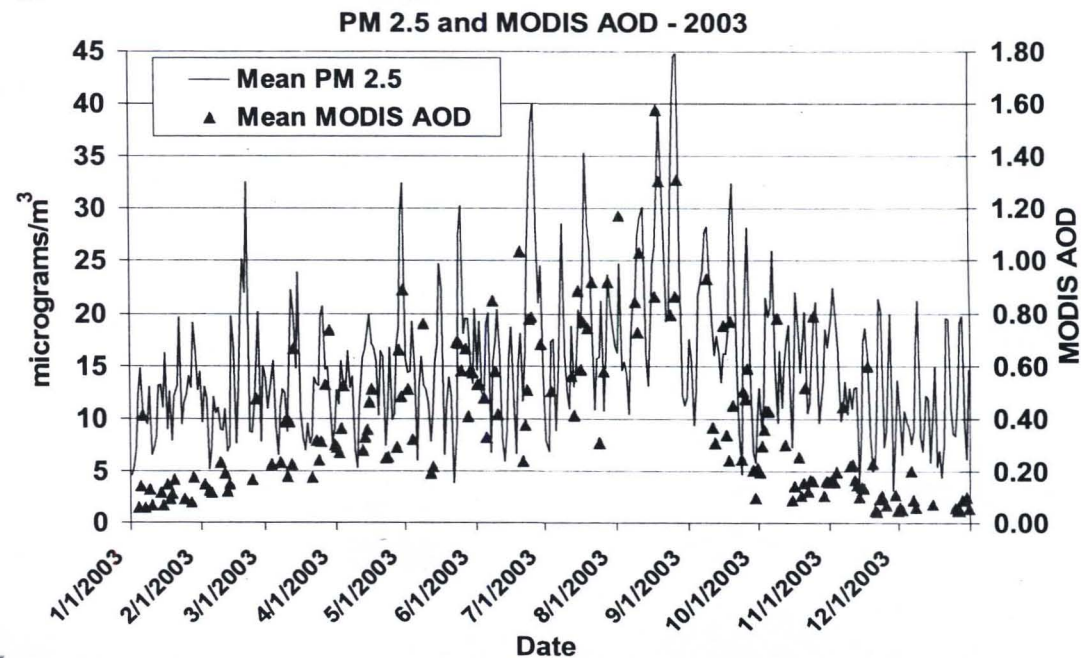


MODIS AOD - PM_{2.5} Relationship



2002

2003



- Daily 5-site means of observed PM_{2.5} and MODIS AOD
- MODIS data not available every day due to cloud cover
- MODIS AOD follows seasonal patterns of PM_{2.5} but not the day-to-day variability in fall and winter



PM 2.5 – MODIS AOD Correlations

April - September

MODIS-Terra MODIS-Aqua

2000 -->	0.579	
2001 -->	0.643	
2002 -->	0.559	0.401
2003 -->	0.661	0.727

- Correlations between PM_{2.5} and MODIS AOD are generally high (> 0.55) for the warm season.
- The lower correlation for MODIS-Aqua in 2002 is for July-September only.



PM_{2.5} Exposure Assessment- Spatial Surfacing

- 1st degree recursive B-spline in x- and y-directions
- Inverse Distance Weighted (IDW)
- Daily surfaces created on a 10x10 km grid
- Variable number of measurements available each day

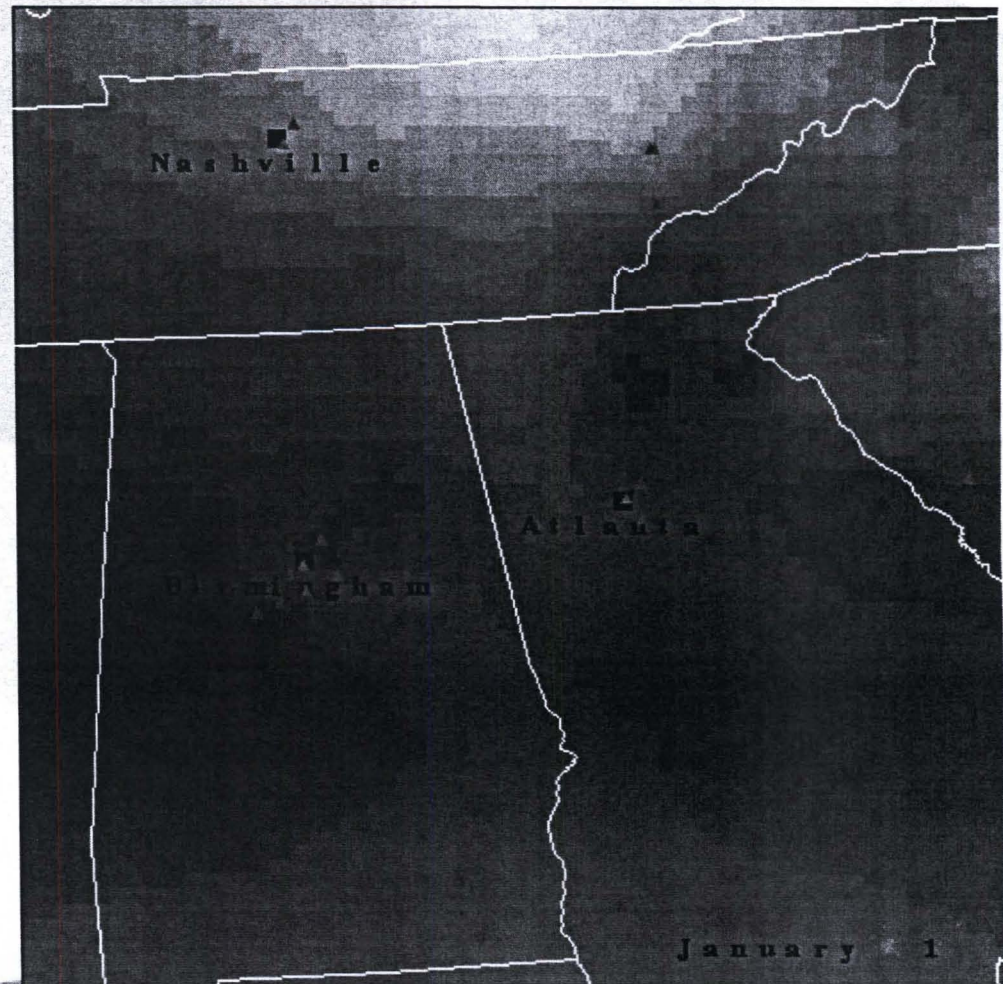


PM_{2.5} Concentration

■ High : 50 $\mu\text{g}/\text{m}^3$

■ Low : 0 $\mu\text{g}/\text{m}^3$

▲ EPA sites



Quality Control Procedure for AQS PM_{2.5} data

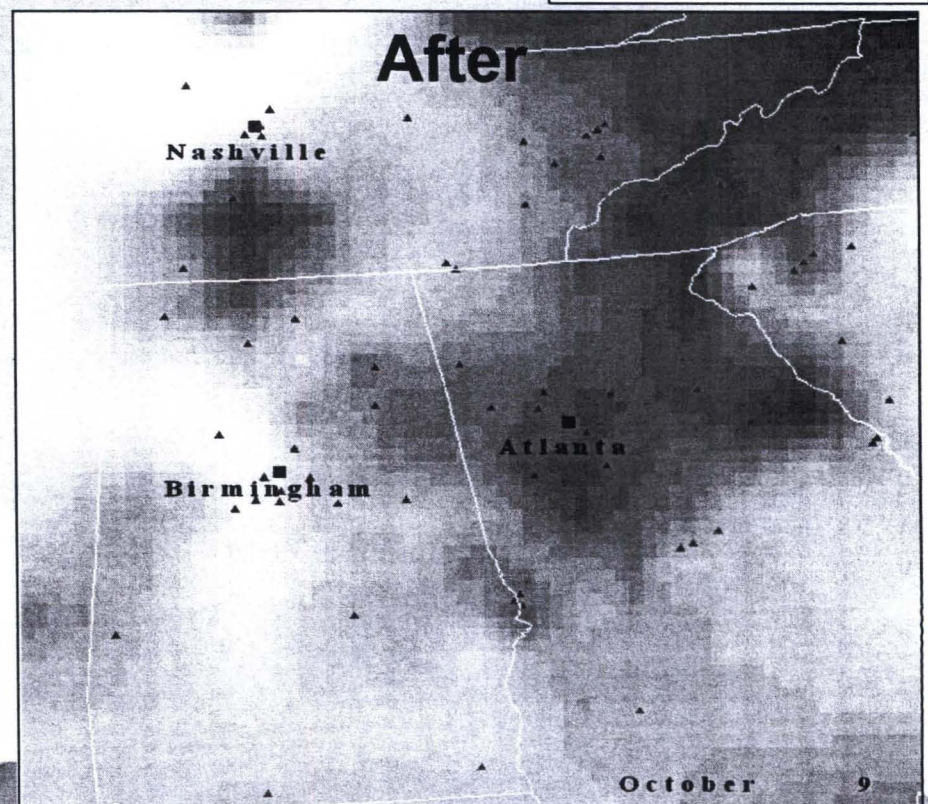
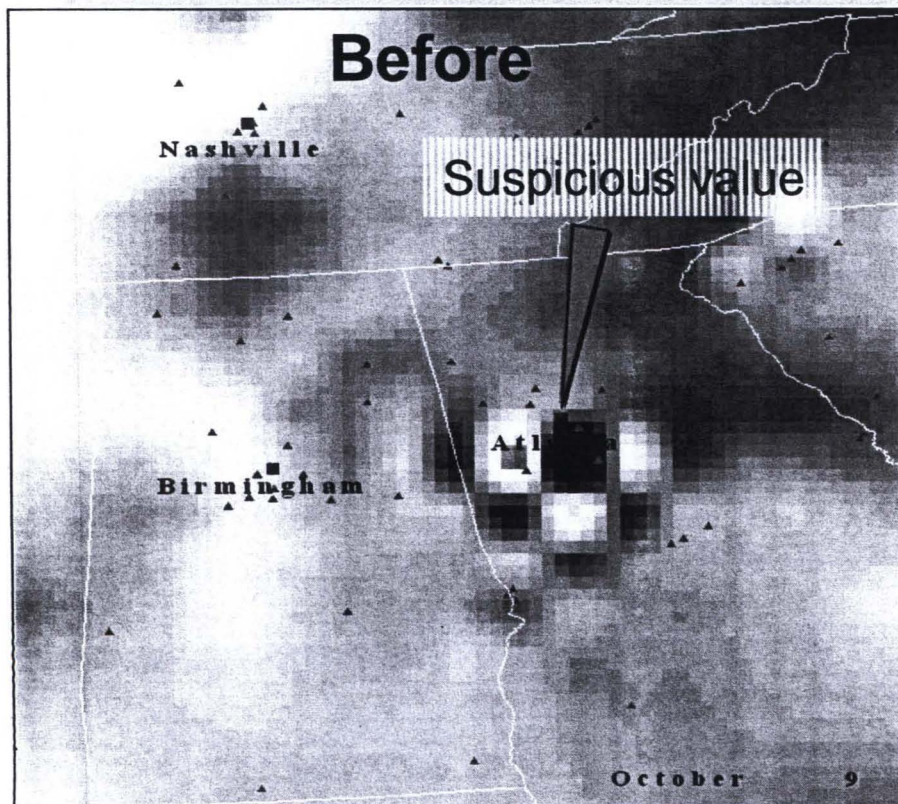
- Eliminates anomalous measurements based on a non-parametric rank-order spatial analysis
- Applied to all daily AQS PM_{2.5} measurements before spatial surfaces are built

PM_{2.5} Concentration

■ High : 50 $\mu\text{g}/\text{m}^3$

■ Low : 0 $\mu\text{g}/\text{m}^3$

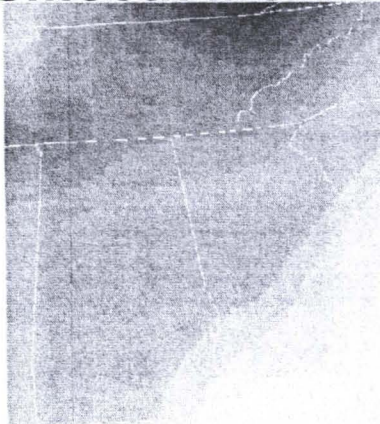
▲ EPA sites



MODIS PM_{2.5} Bias Adjustment

- Assumption: AQS measurements are unbiased relative to the local mean, but MODIS PM_{2.5} estimates may have biases.
- Procedure:
 1. Use a two-step B-spline algorithm to create highly smoothed versions of the MODIS and AQS PM_{2.5} daily surface
 2. Compute the 'Bias' as the difference between the smoothed fields
 3. Subtract the bias from the MODIS PM_{2.5} daily surface to give the 'bias-corrected' MODIS daily surface

Smooth MODIS



65 $\mu\text{g}/\text{m}^3$

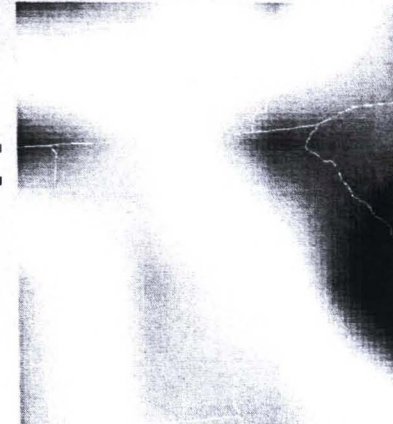
0 $\mu\text{g}/\text{m}^3$

Smooth AQS



=

MODIS Bias



10.6 $\mu\text{g}/\text{m}^3$

-22.9 $\mu\text{g}/\text{m}^3$

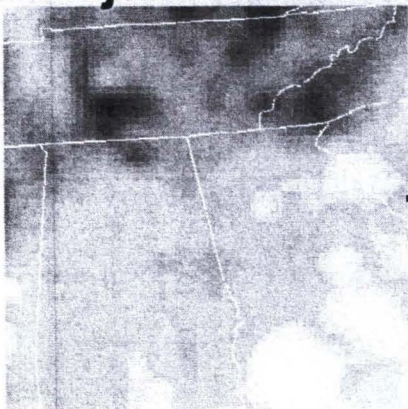


Merging MODIS and AQS PM_{2.5} Data

- MODIS and AQS data have been merged to produce final PM_{2.5} surfaces.

B-Spline Surfacing

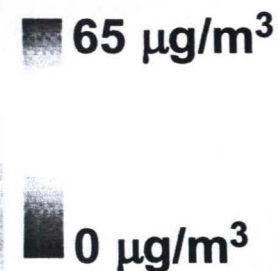
Unadjusted MODIS



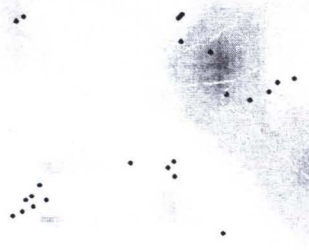
Bias-adjusted MODIS



Merged



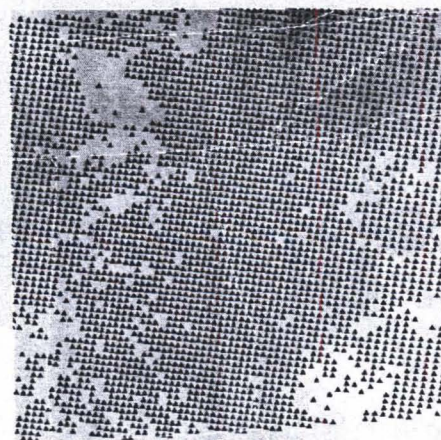
AQS only



Merging MODIS and AQS PM_{2.5} Data

IDW Surfacing

MODIS Only



AQS only



Merged

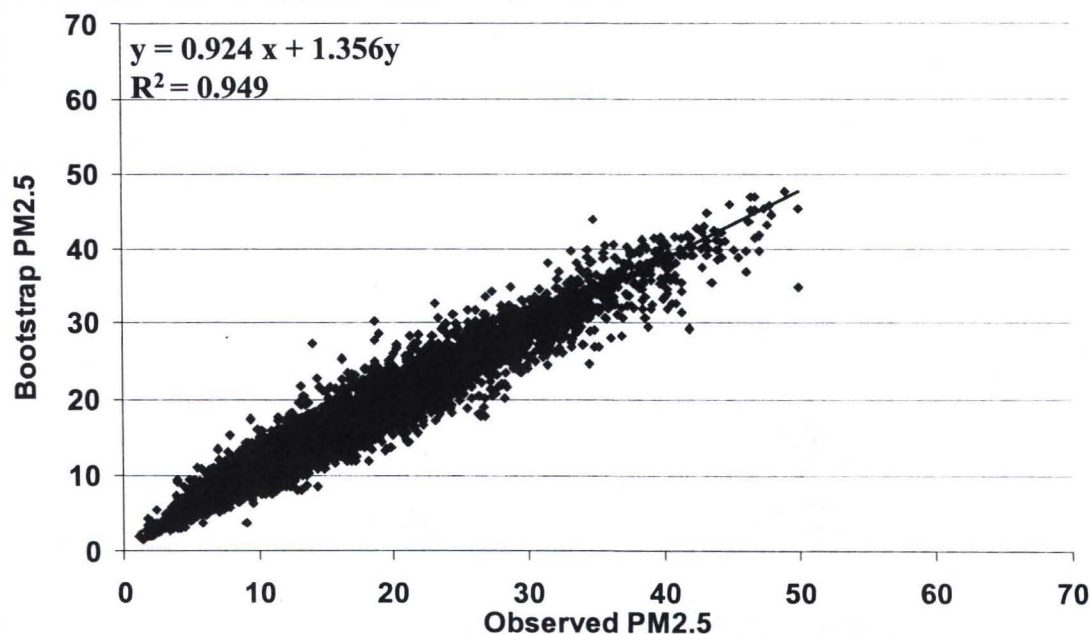
65 $\mu\text{g}/\text{m}^3$

0 $\mu\text{g}/\text{m}^3$



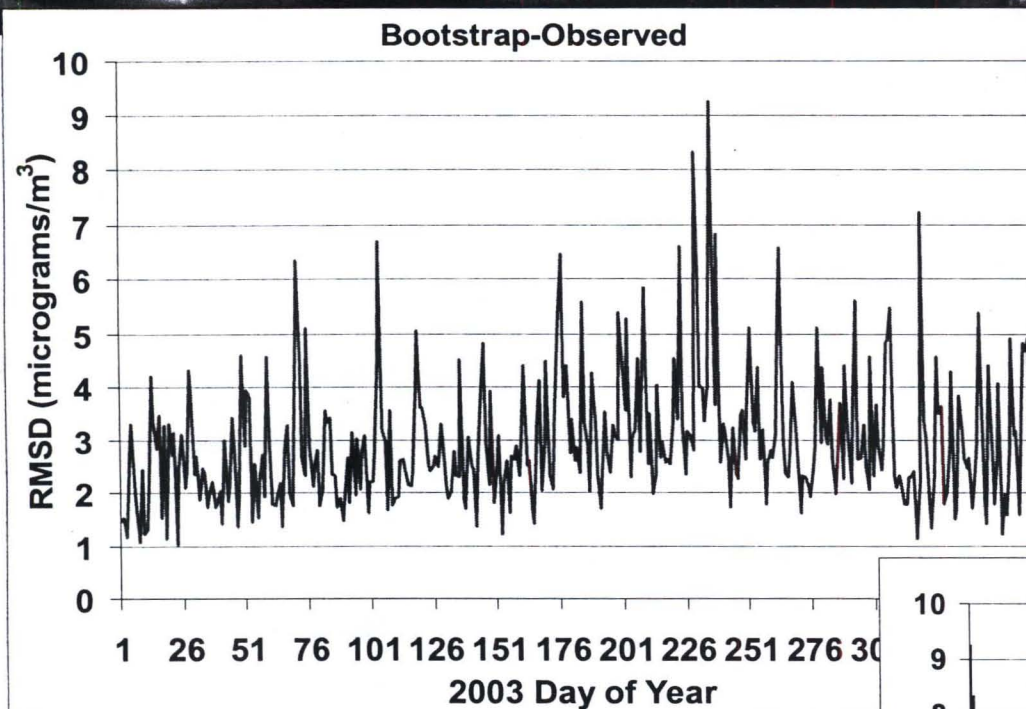
Cross-Validation

- a.k.a. 'bootstrapping' or 'omit-one' analysis
- Objective: Estimate errors associated with daily spatial surfaces
- Procedure:
 1. Omitting one observation, create surface using N-1 observations
 2. Compare value of surface at location of omitted observation with the observed value
 3. Repeat for all observations
 4. Calculate error statistics by day or site

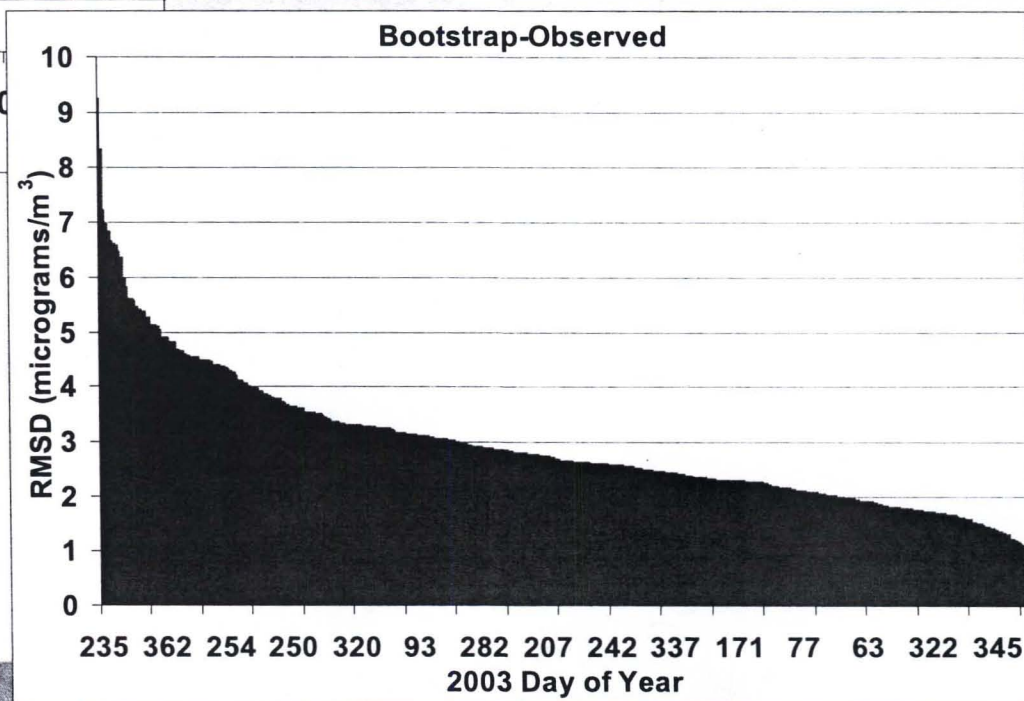


Cross-Validation for B-Spline Surfaces

Daily Error Statistics



Time Series

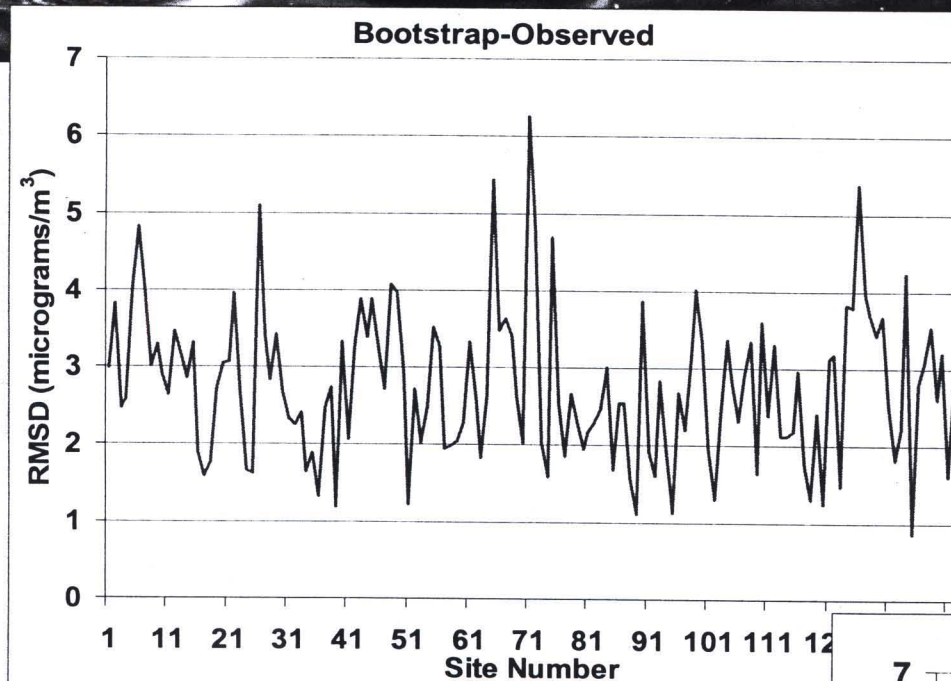


Rank Order

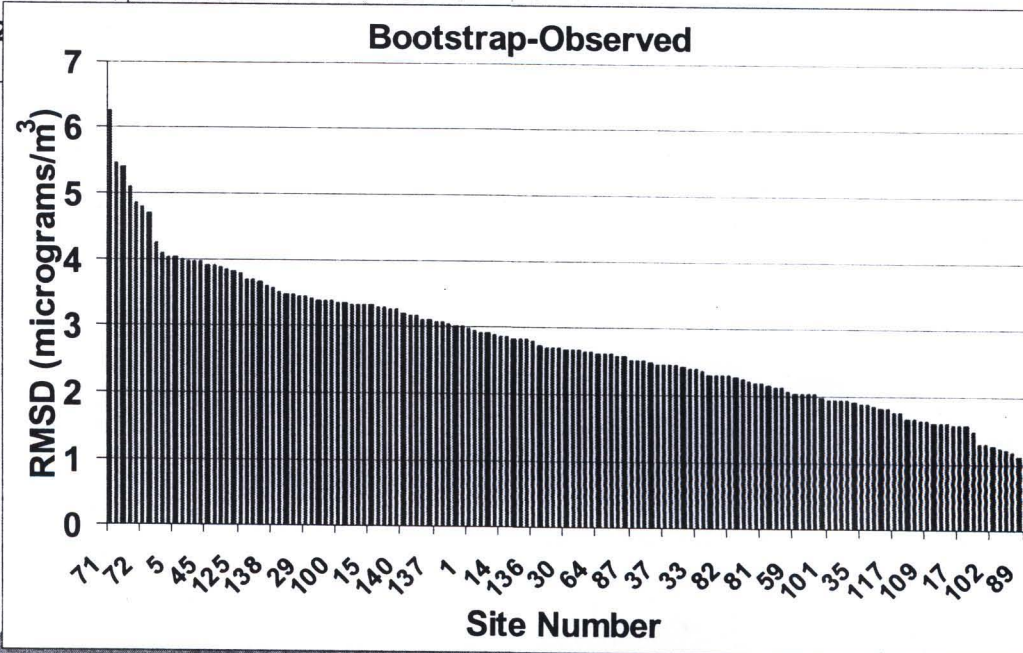


Cross-Validation for B-Spline Surfaces

Error Statistics by Site



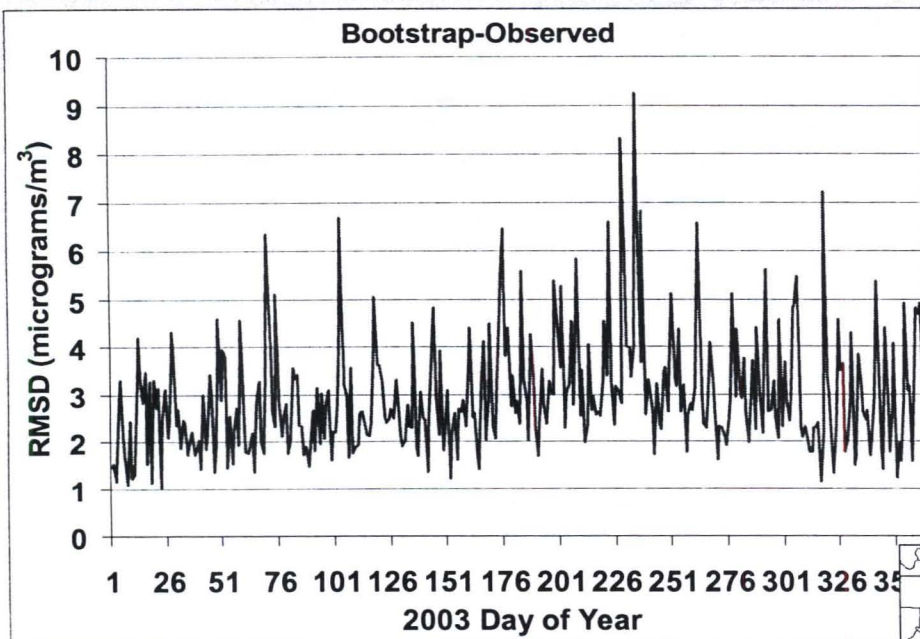
RMSD by Site



Rank Order



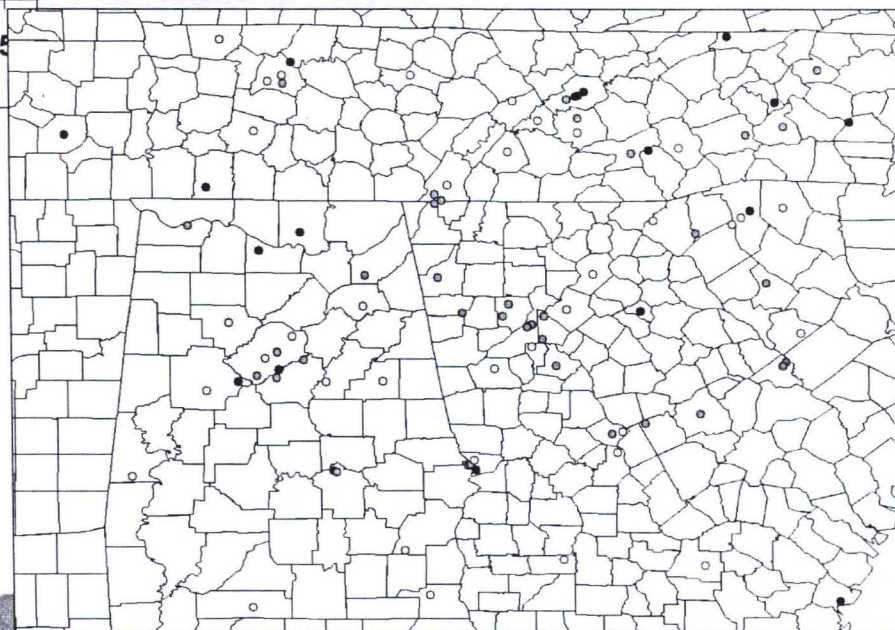
Cross-Validation Error Statistics



Time Series

$$\text{RMSD} = 2.7 \mu\text{g}/\text{m}^3$$

RMSD by Site



Legend

RSMD

BOOT_OBS

- 0.61 - 1.70
- 1.71 - 2.79
- 2.80 - 3.88
- 3.89 - 4.97
- 4.98 - 6.09



Surfacing Methods Comparison

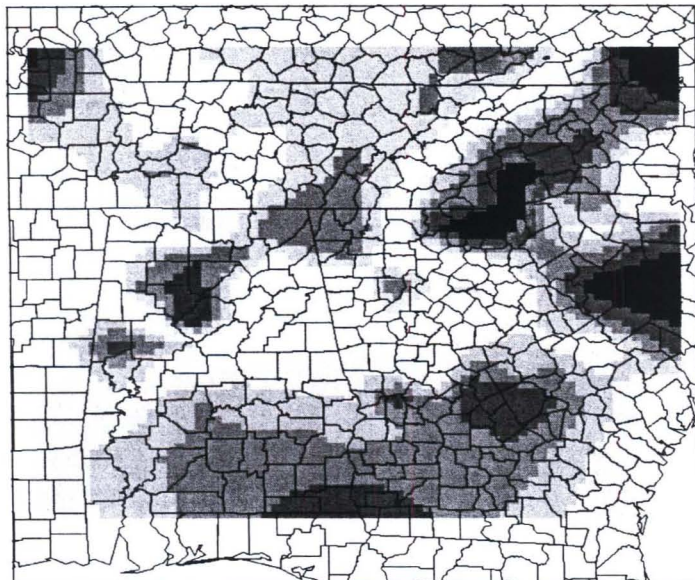
Surfacing Technique and Data Source	RMSD (All Days)	RMSD (Warm Season - Days 91-273)
Bspline, AQS only, no QC	3.30	3.56
Bspline, AQS only, with QC	2.93	3.16
IDW, AQS only	2.45	2.69
B-Spline, merged AQS/MODIS	N/A	2.76
IDW, merged AQS/MODIS	N/A	1.61

Surfacing Technique and Data Source	Improvement
Bspline: QC vs. No QC	12 %
Bspline: AQS only vs. merged AQS/MODIS	16 %
IDW: AQS only vs. merged AQS/MODIS	40 %



Annual Composite Surfaces

PM2.5 B-Spline Surfaces Year 2003 Composite

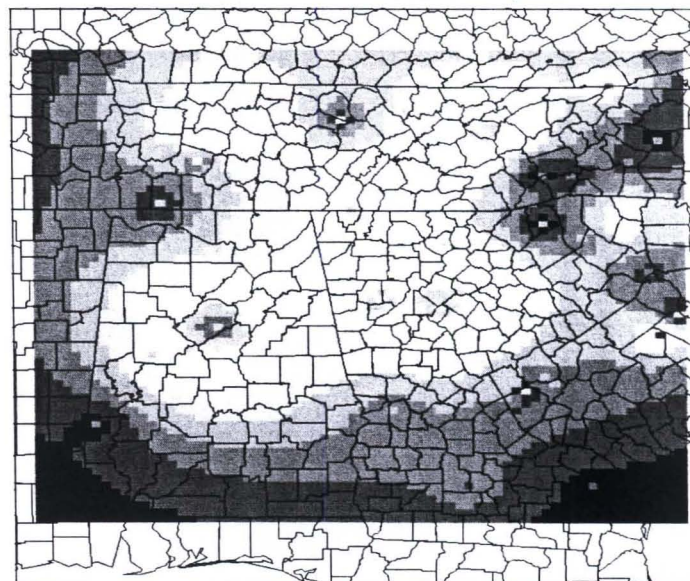


PM2.5 ($\mu\text{g}/\text{m}^3$)

- 10.24 - 11.97
- 11.98 - 12.57
- 12.58 - 12.97
- 12.98 - 13.35
- 13.36 - 13.74
- 13.75 - 14.23
- 14.24 - 14.85
- 14.86 - 15.54
- 15.55 - 16.50
- 16.51 - 18.36

B-Spline

PM2.5 IDW Surfaces Year 2003 Composite



PM2.5 ($\mu\text{g}/\text{m}^3$)

- 10.24 - 11.97
- 11.98 - 12.57
- 12.58 - 12.97
- 12.98 - 13.35
- 13.36 - 13.74
- 13.75 - 14.23
- 14.24 - 14.85
- 14.86 - 15.54
- 15.55 - 16.50
- 16.51 - 18.36

IDW



Linkage of Environmental and Health Data

Health Data Set

Members

LON	LAT	ID	AGE	GENDER	YEAR/MO
-84.207	99.200	1	Child	M	200301
-84.802	99.359	2	Adult	M	200301
-83.798	99.993	4	Child	F	200301

Acute asthma office visits

ID	AGE	LON	LAT	GENDER	DATE
1811	Child	-84.179	99.118	F	1/1/2003
54767	Adult	-84.625	99.802	F	1/1/2003
84580	Adult	-84.679	99.691	F	1/1/2003



*Simulated Data Set. F=female, M=male, A=adult, C=child.

Linkage of Environmental and Health Data

Data Linkage Outputs

Visit counts by grid cell

Date	Cell	PM2.5	FC	MC	FA	MA
200301	1	21.74	1	0	2	0
200301	2	12.79	0	0	0	0
200301	3	12.21	0	1	0	1

PM_{2.5} for each visit

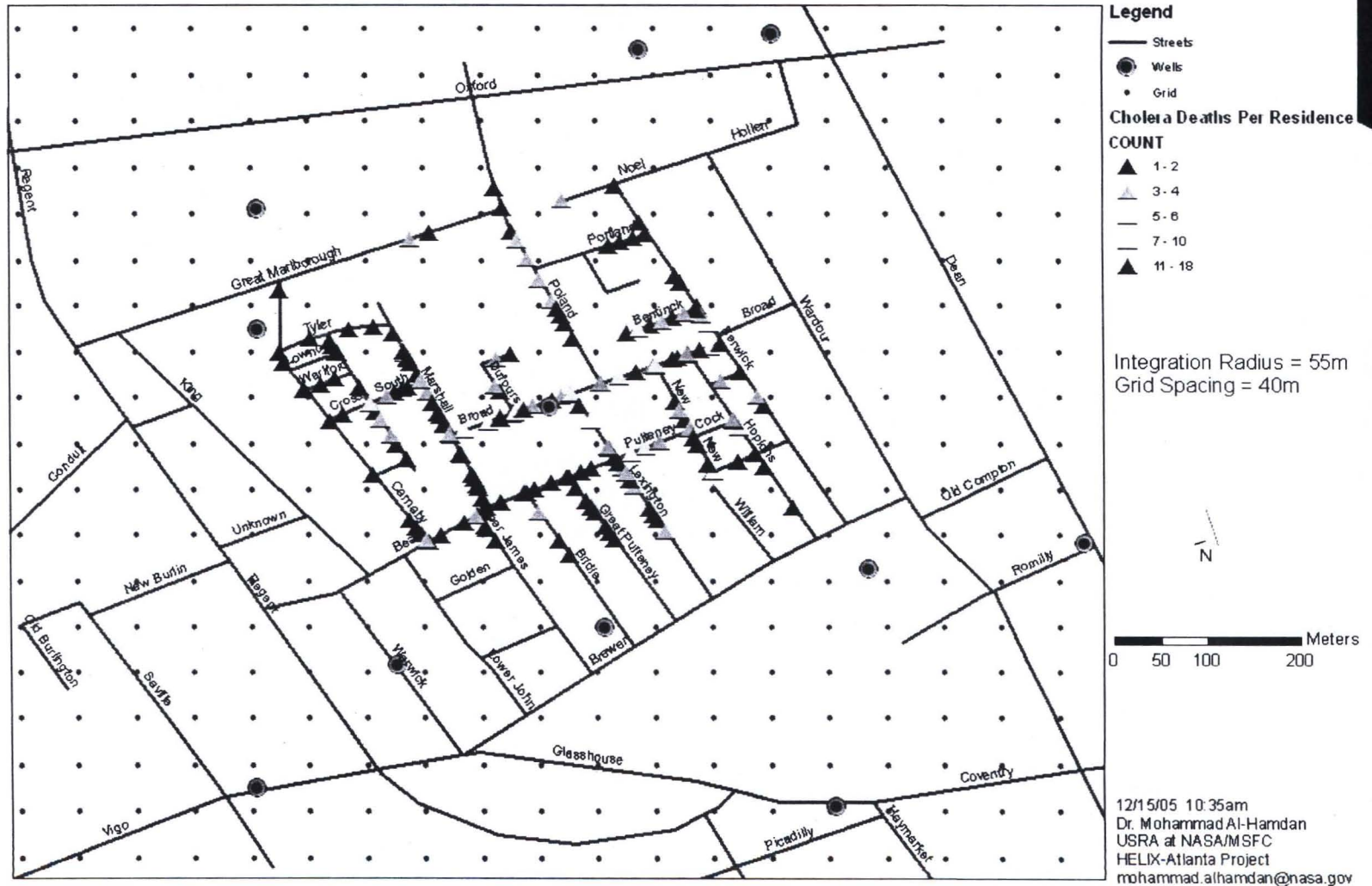
Date	ID	Member	Lat/Lon	Cell	Cell Lat/Lon	County	State	Gender	Age	PM2.5
1	1	1811	99.572 -84.251	1944	99.552 -84.284	Coweta	GA	F	Child	21.74
1	2	15299	99.063 -83.860	1608	99.104 -83.806	Upson	GA	F	Child	12.79
1	2	15879	99.727 -84.369	2079	99.731 -84.403	Fulton	GA	M	Child	12.21



*Simulated Data Set. F=female, M=male, A=adult, C=child.

Public Health Surveillance

Cholera Deaths Soho, London August-September, 1854



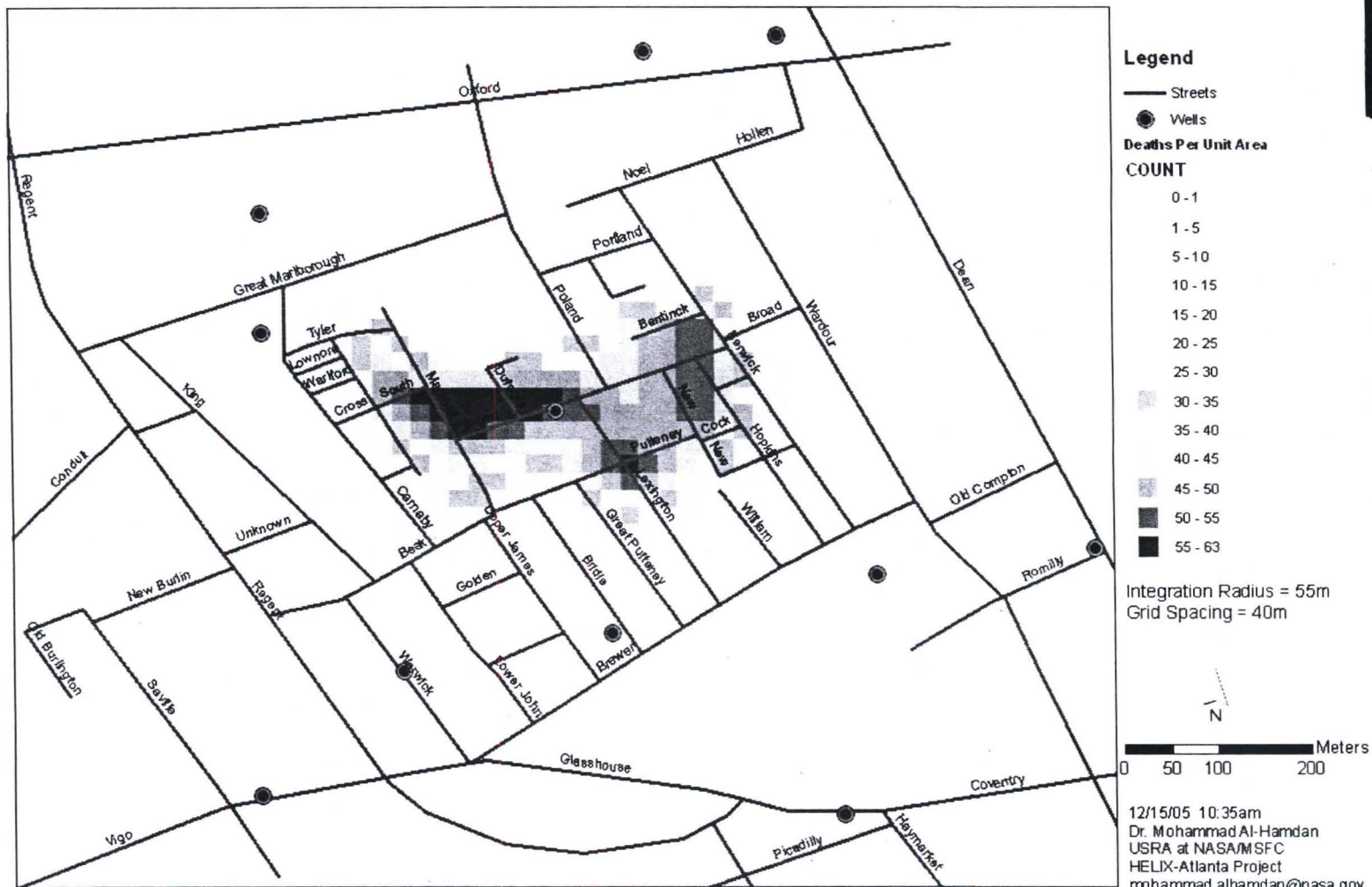
*Original data were published by C.F. Cheffins, Lith, Southampton Buildings, London, England, 1854 in Snow, John. On the Mode of Communication of Cholera, 2nd Ed, John Churchill, New Burlington Street, London, England, 1855.

**Digital Data of Streets, Wells, and Deaths Residences which were used to create this surface were downloaded from the UCLA Department of Epidemiology Website at <http://www.ph.ucla.edu/epi/snow.html>.



Public Health Surveillance

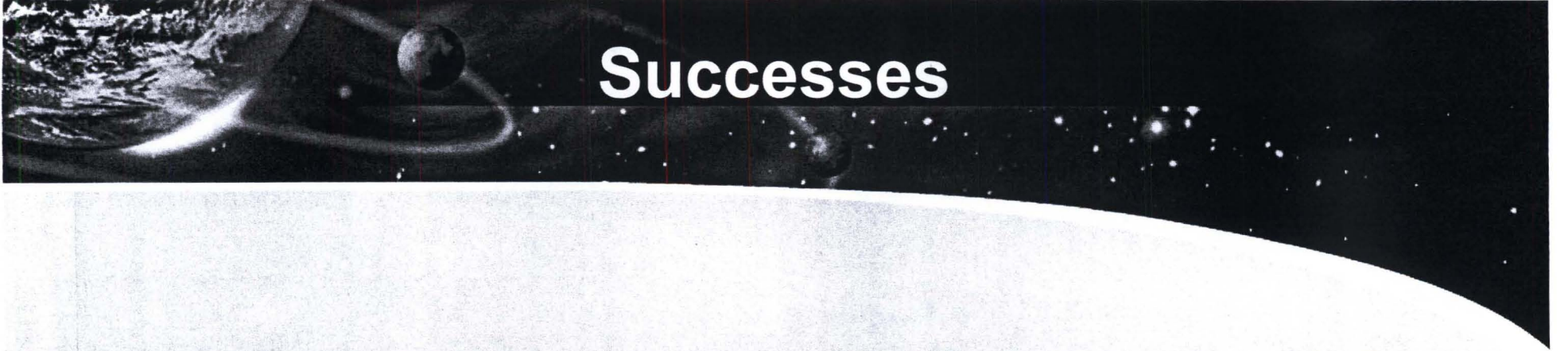
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** Digital Data of Streets, Wells, and Deaths Residences which were used to create this surface were downloaded from the UCLA Department of Epidemiology Website at <http://www.ph.ucla.edu/epi/snow.html>.







Successes

- Proven the feasibility of linking environmental data (MODIS PM_{2.5} estimates and AQS) with health data (asthma)
- Developed algorithms for QC, bias removal, merging MODIS and AQS PM_{2.5} data, and others...
- Negotiated a Business Associate Agreement with a health care provider to enable sharing of Protected Health Information





Team Members and Acknowledgements

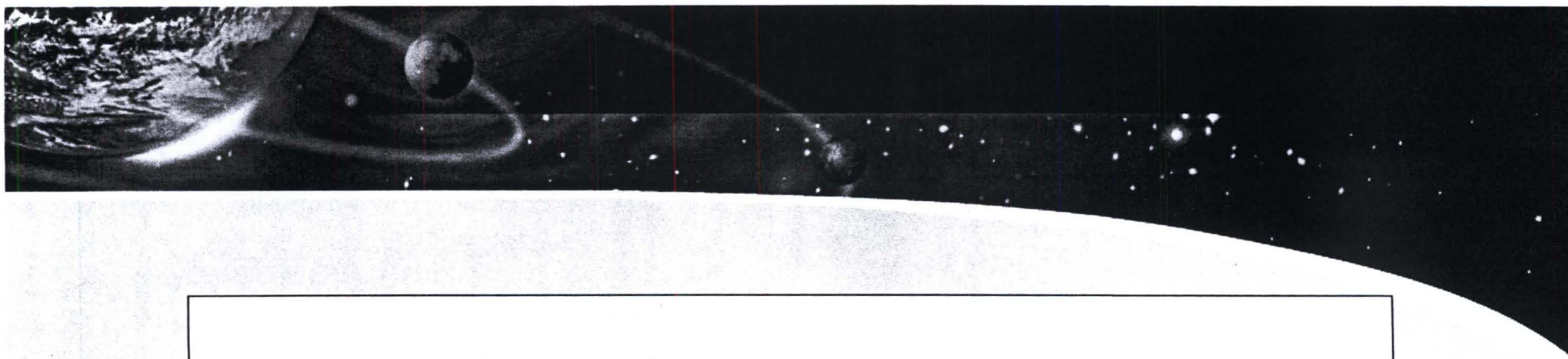
Member's Name, Affiliation

- (Co-Chair) Kafayat Adeniyi, Centers for Disease Control and Prevention,
- (Co-Chair) Solomon Pollard, Environmental Protection Agency (EPA), Region 4
- Mohammad Z. Al-Hamdan, National Aeronautics and Space Administration
- Rob Blake, DeKalb County Board of Health
- David Blaney, Georgia Division of Public Health
- Bill Crosson, National Aeronautics and Space Administration
- Kristen Mertz, Georgia Division of Public Health
- Amanda Sue Niskar, Centers for Disease Control and Prevention
- Dale Quattrochi, National Aeronautics and Space Administration
- Amber Sinclair, Kaiser Permanente
- Allison Stock, Centers for Disease Control and Prevention
- Denis Tolsma, Kaiser Permanente
- Linda Thomas, Environmental Protection Agency, Region 4
- Ntale Kajumba, Environmental Protection Agency, Region 4
- Carolyn Williams, Georgia Division of Public Health

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- Emily Hansen
- HELIX-Atlanta Partners





www.cdc.gov/nceh/tracking

